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# Navigating the Past through an Interactive Geovisualisation-Driven Methodology: Locating a 15th-19th Century Paddy Field as a Source of Agroecological Knowledge

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**Abstract:** The interconnection between the objectives of territorial development and the agro-ecological transition highlights the value of past knowledge in the sustainable management of resources and agro-ecological systems. However, retrospection in rural areas presents difficulties due to a lack of data. This paper contributes to the search for such knowledge from the past by developing an interactive methodology capable of combining heterogeneous sources of information and the activation of local collective memory. Its effectiveness is based on ensuring the interoperability of information and communication in an environment simultaneously shaped by geoinformatics and 3D geo-visualizations. This virtual environment fosters participation and interactivity, supported by representations of the paleo-landscape. Furthermore, synergies were achieved between information sources and their integration into local spatial systems. The application example involved identifying a rice field that existed from the 15th to the 19th century in Thessaly, Greece. It is an interesting case because the location and organization of cultivation in combination with its spatio-temporal coordination ensures the sustainable use of natural resources. It appears that the interplay between information and communication facilitates community participation and the activation of its collective memory as a source of information that enriches the search and local intelligence.

**Keywords:** interactive methodology; paddy field; 3D geovisualisation & public participation; GIS spatial analysis; collective memory

## 1. Introduction

Linking sustainable development to a competitiveness based on distinctiveness, in combination with the move towards agro-ecological transition, leads rural territorial areas to re-approach their historical space and heritage [1–3]. It is, in essence, an attempt to interpret the past in terms of future stakes, which assigns a new dimension and a new role to intangible heritage. The modern crisis of social and production systems better explains the search for new traditional values [4] and the broadening scope of the heritage of knowledge. On the one hand, a more objective and functional approach to heritage is emerging since it tends to acquire a developmental function and the status of a resource in the context of territorial development, while no longer being an obstacle to modernisation [5,6]. One the other hand, as a result of climate change and resource overexploitation, it is accepted that heritage offers, beyond idealistic and timeless values, knowledge and practices for the "soft management" of natural resources [4]. In view of these implications, local communities are realising that the way in which their ancestors appropriated natural resources in the past provides knowledge today about the agro-ecological transition. They understand that this intangible heritage can, as an element of community intelligence [7] respond locally to sustainability goals set at the global level [8,9]. Recognising the value of heritage reintegrates it into local community intelligence in the form of knowledge [10], raising the issues of its identification and integration in local territorial and agro-ecological planning.

In order to take advantage of this new role of heritage, local communities have already started emphasising elements and knowledge from the past [6]. The difficulties faced in rural areas stem from a lack of information and clues since the morphological elements that characterise the space (landscape etc.) cannot remain unchanged by time [3]. This deterioration depends on the duration and intensity of the agricultural production model and its impact on the landscape. On the basis of this model, past knowledge about environmentally-friendly farming and production systems was devalued and abandoned, considered an obstacle to productivity [11]. This development was reinforced by advice coming from the private rather than the public sector [12]. This devaluation of living heritage extended to the social sector, covering much of Mediterranean life (Mediterranean diet, etc.) and was indirectly reproduced by the public education system itself [13,14]. Furthermore, retrospection becomes more difficult when inherited knowledge concerns a farming system and agricultural landscape that no longer exist. It follows from the above that identifying such knowledge is often faced with scarce and heterogeneous information sources. These difficulties are exacerbated when the need to link heritage with the place and its resources requires their dual immaterial and material nature to correspond. Although this cognitive heritage is not always visible, it is detectable when conveyed by local collective memory [2,15]. This means that the participation of local actors in this detection process is decisive. The issue which therefore arises concerns how this memory is activated. If participation is necessary for the identification and interpretation of heritage, then the activation of local collective memory requires the representation of its old reference landscape [2,3,16,17] since it no longer exists.

Applications to date show that the combination of resources, methods and tools and a 3D virtual environment (3D Virtual worlds) can contribute to the collaborative creation of knowledge by actors [18,19]. Advances in geoinformatics and the integration of 3D interactive representations [2] succeed in harnessing the spatial dimension of information in order to reconstruct the landscape by using the concept of local spatial system [20,21]. In this process, the use of GIS is a powerful tool to collect, process and visualise geographic information [22–24]. The science of geoinformatics, by comparing satellite and aerial images of different time periods, helps to identify changes in land use and land cover [25–27]. Highlighting the geometric characteristics of information (position, shape, size, proximity, etc.) in such a virtual environment is a precursor to approaching the semantic dimension of information, i.e. the spatial and functional dimension of heritage. This approach requires the projection of its intangible and material elements in the space, followed by their integration within local spatial subsystems [3,4,21]. However, it has been observed in recent decades that geoinformatics tools and techniques are increasingly being applied by researchers in the management and analysis of information related to material rather than intangible heritage [28,29]. This gap can be addressed through use of representations by geoinformatics to activate visual-spatial intelligence as a component of cognitive intelligence [30]. These representations can be very accurate if old aerial photographs are used. By allowing the positions of different objects in the space to be visualized, 3D-GIS can use the ability of local collective memory actors, on the one hand, to easily perceive shapes, objects and visual information that they can interpret and recall, and on the other hand, to create their own representations in the space based on the oral description that they were given of events and images [31]. Actors benefit from the fact that visualisation allows the invisible to be seen through the transformation of abstract data into visual representations [32] such as the reconstruction of historical landscapes. However, the contribution of interaction to the synergies between heterogeneous sources and types of information, including local collective memory, and to collaborative knowledge creation depends on the interoperability of information and communication between local actors themselves as well as with researchers [33–35]. As several studies note, through the use of high-resolution satellite imagery and Participatory Rural Appraisal (PRA) methods and the creation of interactive 3D environments, 3D participatory GIS (3D PGIS) can support interoperability [2,36]. This interactive environment can contribute to the generation of new information and meta-information

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[3] and highlight the semantic property of information: landscape intelligence, position-functionality within spatial systems.

Making use of the advances achieved in this field, this paper develops a retrospection methodology, supporting the active participation of the local community through 3D geo-visualisation (GIS, spatial analysis, photo interpretation...). The question that this methodology addresses is the extent to which interactivity, as a product of participation and the interoperability of information and communication, can contribute to the identification and interpretation of knowledge, landscapes and spatial systems that have disappeared. The application example involves identifying a paddy field cultivated between the 16th and 19th centuries in the plain of Thessaly, in the area of Farsala. It is an interesting case which perfectly combined the production process with efficient use of natural resources in the siting and organisation of a crop that is demanding in terms of spatio-temporal coordination. Identifying the paddy field presents a challenge for the study as it allows the emergence of inherited knowledge concerning agroecological management. This knowledge is interesting since its rationale is based on nature before the impacts of intensive agriculture and results from spatial, as well as ecological, analysis. This knowledge can help interdisciplinary approaches avoid being limited to ecology or overlooking the environment and the laws of spatial organization [37].

## 2. The Importance of Rice Cultivation and the Framework for Its Organisation in the Balkans

### *2.1. The Framework for Organising Rice Cultivation*

In the Ottoman Empire, rice was perhaps the most important source of food, holding a high place in Ottoman gastronomy [38]. Being highly nutritious, rice was meant for the nutritional needs of the palace, welfare structures, local communities and the army in its campaigns [39]. It was a staple ingredient in food preparation while its by-products (straw, husk, bran,) were utilised by local livestock farming [40]. Its nutritional value and the increasing demand for rice in the growing cities of the 16th century explain the development of paddy fields in the Balkans by the Ottoman administration. Each newly-acquired region quickly fell under the scope of a consistent rice policy which combined land structure, agronomic practices and the market. This policy was expressed through administrative regulations (kânûn-nâmes) adapted to the new regions; where and how the rice fields functioned was regulated by laws. After the conquest, the Ottomans implemented a system to select areas that met the conditions for rice cultivation [40]. The system used criteria such as, on the one hand, water, human resources, arable land, specific soil characteristics and climate and, on the other hand, topographical conditions (river valleys with a low-gradient plain) and irrigation infrastructure [41,42]. Since water flow had to be continuous and manageable, streams were chosen rather than rivers with high banks. Swampy or flood-prone zones were chosen for paddy basins to prevent the spread of malaria. Experts chose flat parcels of land for cultivation, covered with 5-10 cm of water with the use of bunds. Due to proximity to a water source, water was exploited with minimal adjustments and no other crops were planted on the land. Channels extended into neighbouring fields [40] forming a dense network so that the location of the crop changed every year. The extension of drainage and irrigation networks was costly and required skills and coordination. Rice paddy care included techniques for continuous water flow during hot Balkan summers and maintenance of the irrigation system (channels, dams) [43]. Rice was cultivated on land belonging to dynasty members, state officials or institutions and came under a special regime controlled by the central treasury. Rice fields were either leased through the mukataa[1] system or cultivated communally. Due to the cost and difficulty in maintaining paddy fields, rice farmers had a special status[2], with privileges (incentives, tax exemptions) [39,44], which was strictly governed by law (Kânûn-i çeltükçiyân), was hereditary and could not be changed by the registered çeltükci Re'âyâ. Logistics were supported by a system

[1] A tax district or resource area or other source of revenue that the State conceded to individuals for a set period of time

[2] Çeltukçi- Re'âyâ: rice farmers, supervised workers, landless and tax exempt persons

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which monitored production[3] [45]. The farmers' work was monitored by an individual under the supervision of a person in charge of the rice fields. Farmers and those responsible for cleaning the channels were involved in the management of the mukataa [40]. The organiser (re'îs) was responsible for planning cultivation, filling the channel and acquiring the seeds from the administration, or landowner when it was a communal cultivation or mukātaa. He was also responsible for irrigation and flooding the land before sowing. He specified the requirements to procure workers for the harvest, their remuneration[4] [44] and the production-disposal of seeds. He was in charge of the collection-cleaning and marketing of rice, safeguarding the Palace's stock. He arrested and punished anyone who stole rice or allowed their animals onto the paddy field, confiscated stolen rice and enforced the rules without opposition. The local authorities had to support the organiser to prevent loss of public goods.

### *2.2. Examples of Rice Cultivation in Thessaly and Farsala*

SW Thessaly was fully conquered by the Ottomans at the beginning of the 15th century and was selected as an area for rice cultivation. Information from the Ottoman registers (1455, 1506, 1521) and the regulations regarding the organisation of rice cultivation[5] confirm that shortly afterwards, in the mid-15th century, rice was systematically cultivated in Thessaly and Farsala, as well as in the wider region of Rumelia. The main characteristic of rice cultivation in SW Thessaly was that, unlike other areas of the Empire, it was not located on the hillsides harnessing rainfall. As the average rainfall in Thessaly did not exceed 800 mm per year, land was chosen which was crossed by perennial streams, irrigated or flooded [46] or located next to springs (Chtouri, Vrysia, Tabakos). After the conquest, Turkish Yuruk nomads settled in these areas-locations of SW Thessaly. However, these were small paddy fields which were classed as special production spaces and, in combination with the presence of a Muslim population, support the view that rice was grown mostly to meet local needs [47]. The area does not seem to belong to the zones supplying distant markets (İstanbul, Anadolu) like the large rice-growing zones (Plovdiv, Serres, Feres, etc.). It seems that here, as in the rest of the empire, rice cultivation occurred in the first period after the conquest on timar lands for timariots. Thereafter, despite the increasing internal demand, rice cultivation in Thessaly was limited after the conquest of Egypt, the main supplier of the Ottoman market from then on [45].

Historical analysis of the Farsala area reveals the existence of rice paddies in the mid-15th century, while the first censuses after Thessaly joined the Greek state, which coincide with the departure of Muslim Thessalians for Turkey (1883-1913), confirm the disappearance of the crop. The abandonment of rice cultivation signalled the loss of relevant accumulated knowledge for this area.

## 3. Materials and Methods

### *3.1. Case Study*

The present research was conducted in SW lowland Thessaly, in the community of Lefki. Topographically, the area is characterised by flat-light slopes with an altitude of 100 to 120 metres. The river Enipeas flows along its eastern border. The economy has always been based on polyculture and mixed production systems (pastoral farming and annual crops, cotton, maize, wheat, barley and vegetables), while today it is trying to move away from system of quasi-monoculture based on cotton.

The climate is continental, with hot, dry summers and cold winters and an average temperature of 16◦C (Figure 1). Its population went from 400 inhabitants in 1981, to 220 in 2021.

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[3] Document on rice, sent (16th century) to administrations (Sanjaks) in the Balkans to be implemented

[4] Due to labour shortages, some areas used nomads or workers

[5] The first law for the Sanjak of Trikala, during the time of Muhammad the Conqueror, "Tırhala Yasaknamesi". It concerns rice cultivation (rice paddy locations and issues related to the rice market).

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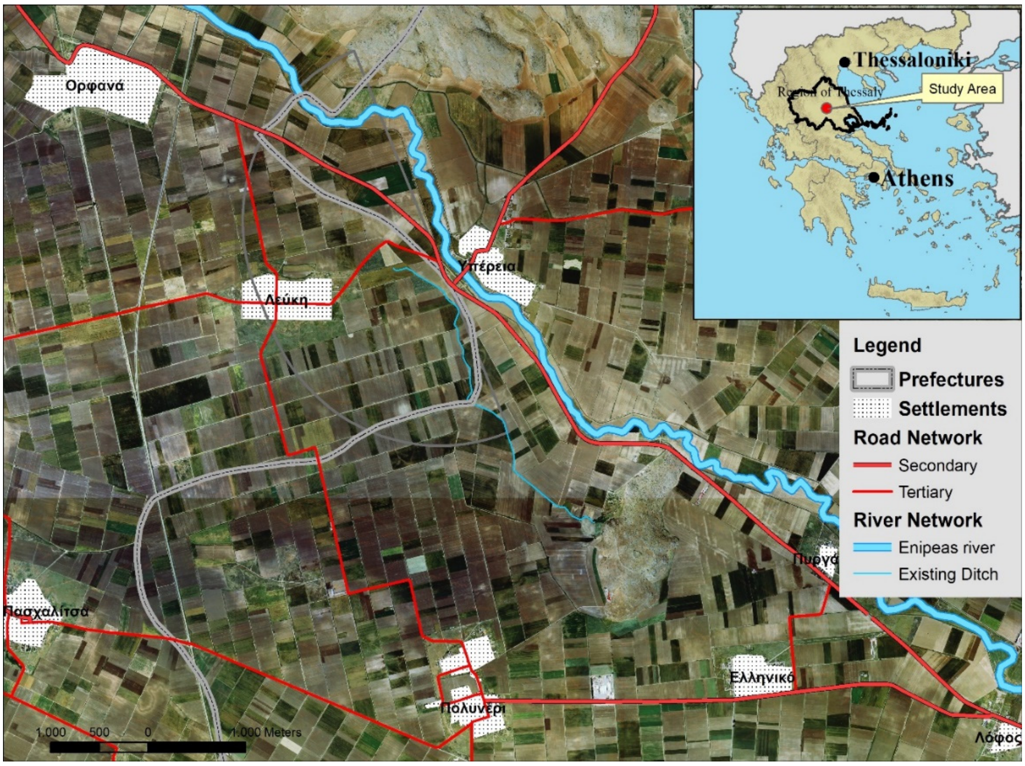


**Figure 1.** Study area, Lefki, Region of Thessaly (Greece).

*3.2. Study Period and Data Collection*

The investigation of the paddy field location in the region of Farsala was based primarily on written reports of the agricultural production systems in the official Ottoman archives of the 16th century. Specifically, the censuses of 1506 and 1521 mention the rice-growing zone in the villages of Vrysia (Başhpinar), Ano Orphana (Çeltküçi Bayezid) and the town of Farsala [48]. In recent years there has been a surprising increase in the publication of both these archives and various related studies which, together with descriptions by travellers, contribute to the understanding of land use, production systems and landscapes of the period [49,50]. These sources include information from the agricultural census of 1911 [51], as well as from residents, which confirm the disappearance of the crop in the area. In contrast, a more accurate location for the paddy field is given by the published account of the English traveller William Leake who crossed the area in late 1810, providing information about the anthropogenic and natural environment [52]. He only identified paddy fields in the neighbouring village of Lefki (formerly called Hamedli or Hamekli), which is located 2.5 km south of a paddy field recorded in the 1521 census, i.e. in the village of Çeltküçi Bayezid. This move is presumed to be due to the frequent flooding of the original position.

Additional information on the paddy field location is provided by the aerial photographs from 1945, i.e. before land consolidation, which also confirm the disappearance of rice cultivation in the area. The large number of channels is also noted, but this was reduced by agricultural consolidation after 1970. In addition, topographical and descriptive data were collected, processed and coded in the form of GIS:

- Topographical diagrams with a scale of 1/5000. They show the elevation (contour lines/isohypse at 4 m intervals), toponyms, the hydrographic and the road network. (GIS, https://www.gys.gr/hmgs-geoindex_en.html).
- Black and white aerial photographs (APs) from 1945 with a scale of 1:4000 and colour APs from 2017 with a scale of 1:5000, with the creation of corresponding orthophoto maps (ordered from the Hellenic Cadastre, https://www. ktimatologio.gr/el).

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- A field study in the communities of the study area and meetings with residents to obtain information on the existence of streams, pre-1970 crops and soil quality through 3D representations.

*3.3. Methodology*

The methodology for the identification of the paddy field in the study area aims to overcome the incompatibility between the different sources of information and the subjectivity of the narratives, by combining three types of information (narratives, other sources, local collective memory) and 3D modelling. The goal is, on the one hand, interaction between the different and exchanges between actors based on their recollections, memories and experiences and, on the other hand, the extension in time of their interpretative contribution.

The aim of the **first phase of the methodology** is the spatialisation of information. In view of the spatial dimension of the elements, it attempts to integrate them as positions, based on a rationale of interdependence, within spatio-functional entities (settlements, irrigation zones, land for food crops, etc.) and systemic relationships (crop rotation). Retrospection will be based on information classed in three groups: spatial (position, form, surface area, orientation), functional (organisation of crops, irrigation), and temporal (crop rotation). The **second phase** involves the creation of a virtual environment with the help and further activation of local collective memory, by enabling the active participation of local actors and their collaboration with the researchers.

The two phases are linked through an interactive process that seeks to construct, in terms of integration, the spatial information of the representations and the virtual navigation environment.

The methodology was organised in three interdependent steps:

- Collection and geocoding of historical and contemporary information from bibliographical sources with the use of GIS.
- Use of 3D geovisualisations to obtain information from local actors.
- Application of geoinformatics methods (spatial analysis) to reveal and identify elements.

The following figure illustrates the methodological chain which incorporates the above-mentioned steps (Figure 2).

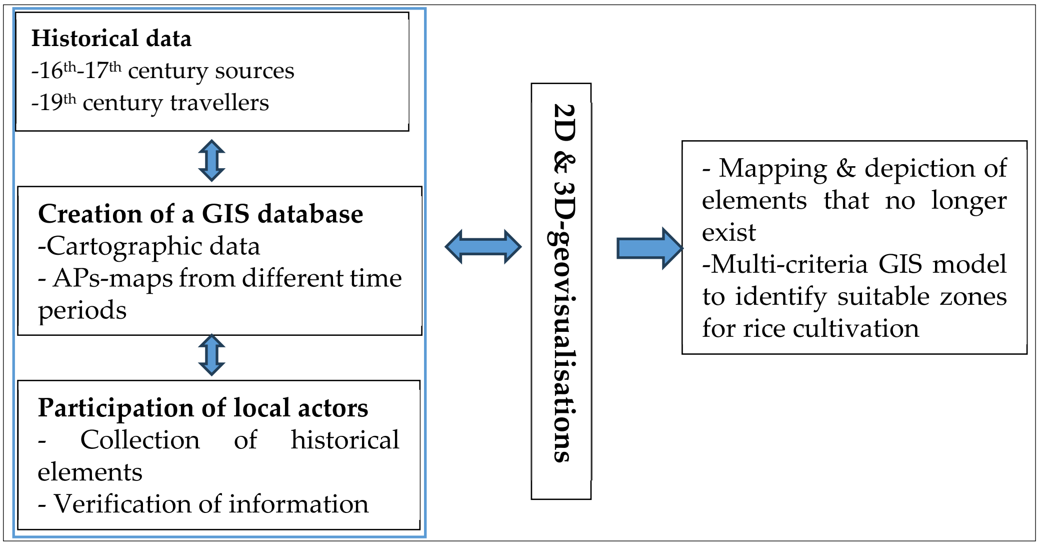


**Figure 2.** Flowchart of the proposed methodology.

Each of the three steps is described below:

3.3.1. Collection of Historical and Current Information

Demarcating the paddy field faced difficulties since: (a) according to the agricultural censuses, since the beginning of the 20th century, rice is no longer cultivated, and (b) after 1965 land

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consolidation changed the landscape and the paddy field basin. The bibliographic references, their codification and the focus on the spatial dimension of the information constituted the first step of the methodology. The accounts of Leake, the 19th- century traveller, were included in these reports after having previously mapped the route he followed. At the same time, research was conducted in Ottoman archives on rice cultivation from the 16th to the 19th century in the Balkans and in the study area. A GIS database and a base map were created in a GIS environment. Then, the historical information was coded and spatially stored in the digital geospatial database. Information on land use/land cover, settlement locations, and the road and hydrographic networks was then recorded for the period before land consolidation, i.e. before the 1970s. In addition, a detailed elevation map and a corresponding slope map of the area were created (Figure 3).

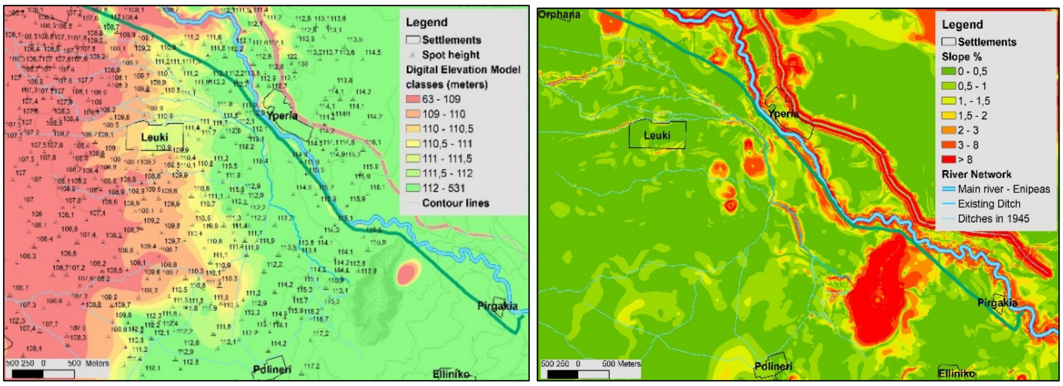


**Figure 3.** Mapping of elevation and creation of a slope map.

The cartographic data were enriched with the results of the processing-comparison between the 1945 and 2017 aerial photographs. The main working hypothesis was that the hydrographic network depicted in the 1945 APs remained the same from the 16th century until the 1970s, before land consolidation brought about significant changes. Information on the old hydrographic network was stored in the digital geospatial database.

The map below depicts the channels before land consolidation, the small lake in Chtouri, which was drained and is now cultivated land and lastly, the route taken by Leake after the village of Orphana and up to "Xtouri" (Figure 4).

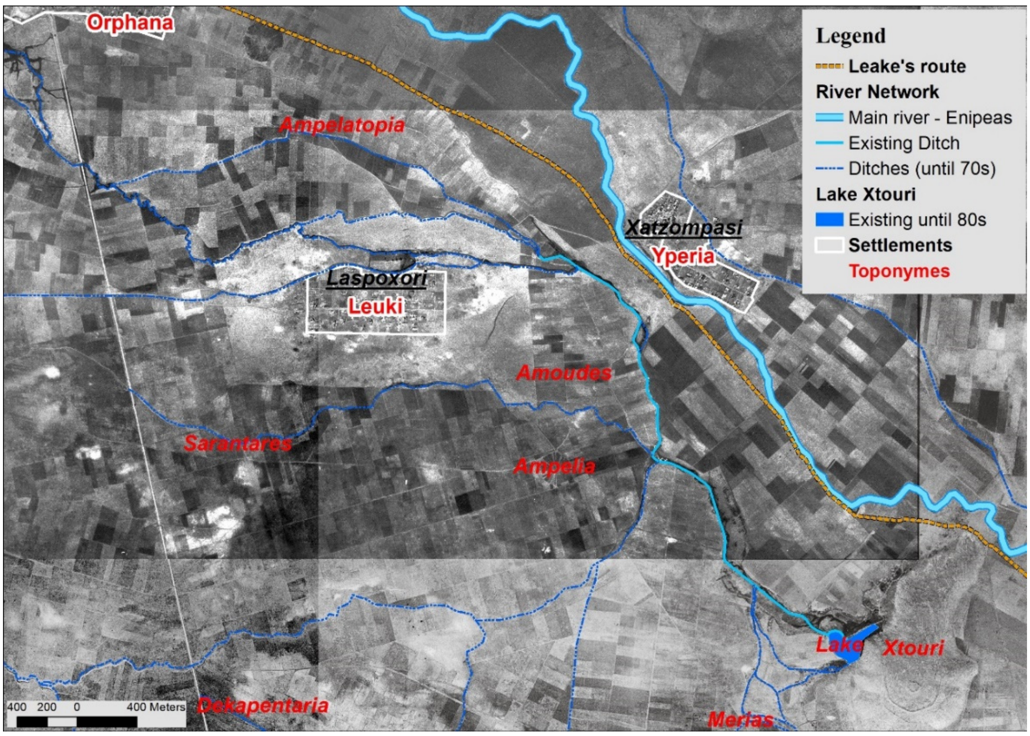

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**Figure 4.** Mapping of the hydrographic network with the use of aerial photos from 1945.

3.3.2. Participatory Processes with the Use of 3D Geovisualisations

The objective in the second step was to complete the creation of 3D GIS geovisualisations to support the participatory process with the residents of the community of Lefki. In this context, 3D GIS interactive cartographic data were first created. The geospatial information coded in the previous step was rendered in a 3D environment (hydrographic and road network, toponyms, settlement locations, etc.). More specifically, the 3D GIS representations refer to two time periods: (a) the current landscape and spatial structures and (b) the form and surface area of the villages and the landscape in 1945. The depiction of the current landscape was used as a bridge to transition to the old landscape. The following figure shows snapshots of the two interactive maps (Figure 5). Both the land structures before consolidation, which were characterised by small plots and a dense hydrographic network which extended a short distance east and northwest of the settlement of Lefki, are evident in the 1945 landscape.

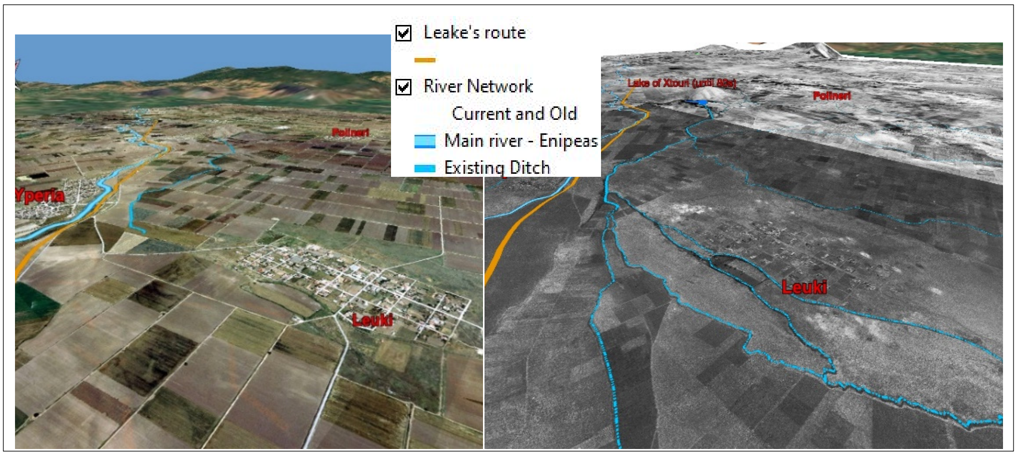


**Figure 5.** 3D GIS visualizations of the contemporary (left image) and past (1945) landscape.

Next, the 3D models (3D geovisualisations) were presented to residents and the diaspora of the community of Lefki in order to collect information with a bottom-up approach. Residents, as carriers of collective local memory are an important source of knowledge about the landscape, land use, farming systems, water management, etc. in the community of the past. Interviewees had to meet the following criteria:

- be willing to share information,
- be born in the 1950s or earlier,
- be knowledgeable about the area (farmers by profession) with good sense of orientation.

The main objective of the village meetings was to acquire information about the use of channels, flood zones, soil characteristics, agricultural land use and community pasture boundaries, before land consolidation (1950s) (Figure 6). The 3D interactive model was used in each meeting as a key tool to depict elements of the space, for visibility and time distance analysis, to help participants quickly and easily indicate positions of interest and for the research team to record the information with a spatial reference. The spatial information collected was coded and stored in the geospatial database.

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**Figure 6.** Meetings with local residents.

Based on the process above and with the participation of residents, the old hydrographic network was verified and two flood-prone areas, which are dependent on the frequency and range of the phenomenon, were identified: (a) the most flood-prone zone is located on the eastern boundary of the community next to the path of the river Enipeas and (b) more minor flooding occurred northeast of the village, at the branching of the central ditch into smaller ones. In addition, uses that existed until the mid-20th century were identified to the north and northeast of the settlement, food crops to the southeast as well as the location of the watermill and of the residence (konak) of the large landowner. Lastly, the residential zone of the village in the 18th century was delimited. All the information was rendered in the 3D-GIS environment after being coded in the geodatabase (Figure 7).

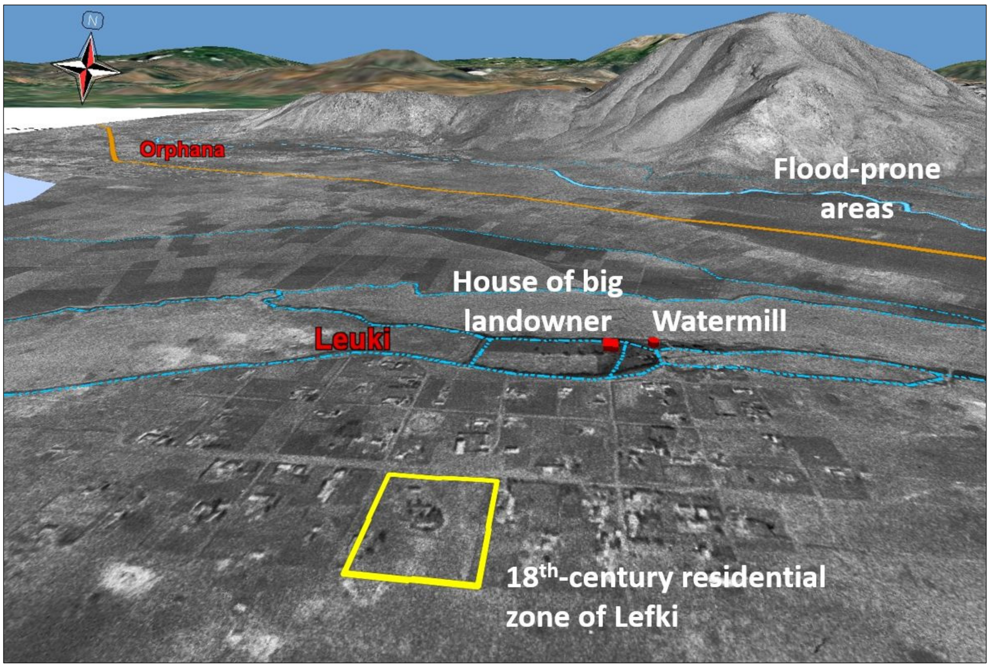


**Figure 7.** Collecting information from local residents by applying 3D PGIS to the study area.

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3.3.3. Criteria for the Identification of Suitability Zones

The methodology of spatial analysis was applied in order to identify the suitability zones for rice cultivation by combining spatial variables such as: (a) soil-topographical characteristics; (b) density and structure of the hydrographic network as mapped using the 1945 APs; (c) distance from the Enipeas River in order to map the areas vulnerable to flooding; (d) distance from the water supply source (Chtiouri lake) to allow for its temperature to rise to levels suitable for growing rice.

1. Soil & Topographical Characteristics

The determining factor for the selection of the rice paddy location is specific soil characteristics such as those found in the areas crossed by the ditch and its smaller branches, namely the eastern and northeastern zones of the community (Figure 4). These areas are characterised by alluvial soils, i.e. deposits of clay, sand, gravel and other loose materials produced by flooding, making these soils the most fertile.

The next element concerns the identification of the flattest surfaces based on slopes and elevation differences in the wider area of the settlement of Lefki (Figure 3). The topographical analysis revealed that, in the areas with the densest hydrographic network, i.e. north - northeast of the settlement, and for a distance of about 1.5 km (total area of 200 ha), the differences in elevation do not exceed 2 m (111-109 m). The small difference in elevation within this almost flat zone to the northeast of the village allows water to be channelled downstream and partly upstream.

Lastly, swamps in the area north-west of the village of Lefki were identified and delimited. These swamps existed until the middle of the 20$^{th}$ century.

2. Irrigation Infrastructure

Continuous irrigation of the paddy field was ensured through small channels connected to the central ditch which was fed by the adjacent spring-lake of Chtouri (3.5 km from the village of Lefki) (Figure 4). Until 1960 the supply from the spring was continuous and significant, with fluctuations between the winter and summer seasons. The central ditch ran a course of about 2 km from its source to the north before following a north-western direction, passing the village after about 1.5 km. At the height of the village of Lefki and at a distance of 700 m, the first fork in the ditch appeared and 500 m later the second, in a westerly direction. In this zone, which extends north and northeast of the settlement, there was a dense branching of natural and artificial channels which facilitated the discretionary channelling of water through small dams. This dense network of channels enabled and supported the organisation of rice cultivation and the necessary plot rotation.

3. Multicriteria Model

The combination of soil characteristics and use (e.g. legume zone), the gentle slopes, the direction of the channels and of the prevailing winds (west-southwesterly and northeasterly winds), provide a first insight into the possible siting zones and the layout of the paddy basin and the bunds. The GIS multi-criteria model developed was based on the Analytical Hierarchy Process as proposed by Saaty [53]. Each criterion was classified and standardized into 5 suitability categories: High suitability, Moderate suitability, Marginal suitability, Currently unsuitable, Permanently unsuitable [54]. This classification was based on the literature regarding the necessity of water as well as taking into account the lack of mechanical means for cultivation. The four main criteria with their respective categorisation are presented in the table below (Table 1).

**Table 1.** Standardisation of criteria for the suitability of paddy fields.

| Suitability classes | Slope % | Distance from Ditches | Distance to river Enipeas | Distance to source Xtouri |
|---|---|---|---|---|
| **Permanently unsuitable** | >8 | >200 | 0-200 | 0-200 |
| **Currently unsuitable** | 3-8 | 150-200 | 200-500 | 200-500 |
| **Marginal suitability** | 1-3 | 100-150 | 500-1000 | 500-1000 |

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| | | | | |
|---|---|---|---|---|
| **Moderate suitability** | 0.5-1 | 10-100 | 1000-1500 | 1000-1500 |
| **High suitability** | 0-0.5 | 0-50 | >1500 | >1500 |

Next, for the more precise identification of the paddy field location, information provided by travellers and the local community was used. In particular, Leake reported that the village of Lefki was located at a distance of 1 mile to the east of the village of Hadziombasi, surrounded by paddy fields. Therefore, the criterion of the visibility of the paddy field (< 1 mile) from the position of the traveller is added to the multi-criteria model.

The final step in the methodology involved analysis within the candidate suitability zones at the level of the rice paddy basin. Techniques and practices related to the organisation of rice cultivation in the space (basin orientation) and on plots (constructing bunds, etc.) within the space were examined. The analysis of wind direction in relation to the possible location and layout of the paddy field was also an important element.

## 4. Results

### *4.1. Map of Suitability Zones*

The map resulting from the multi-criteria model identifies the zones of high suitability for rice cultivation in the north-northeastern part of the village and the boundaries of the community of Lefki (Figure 8). The analysis focuses on the first two suitability categories: (a) the High suitability zone found to the north of the village and (b) the Moderate suitability zone, which is adjacent to the former and surrounds the village.

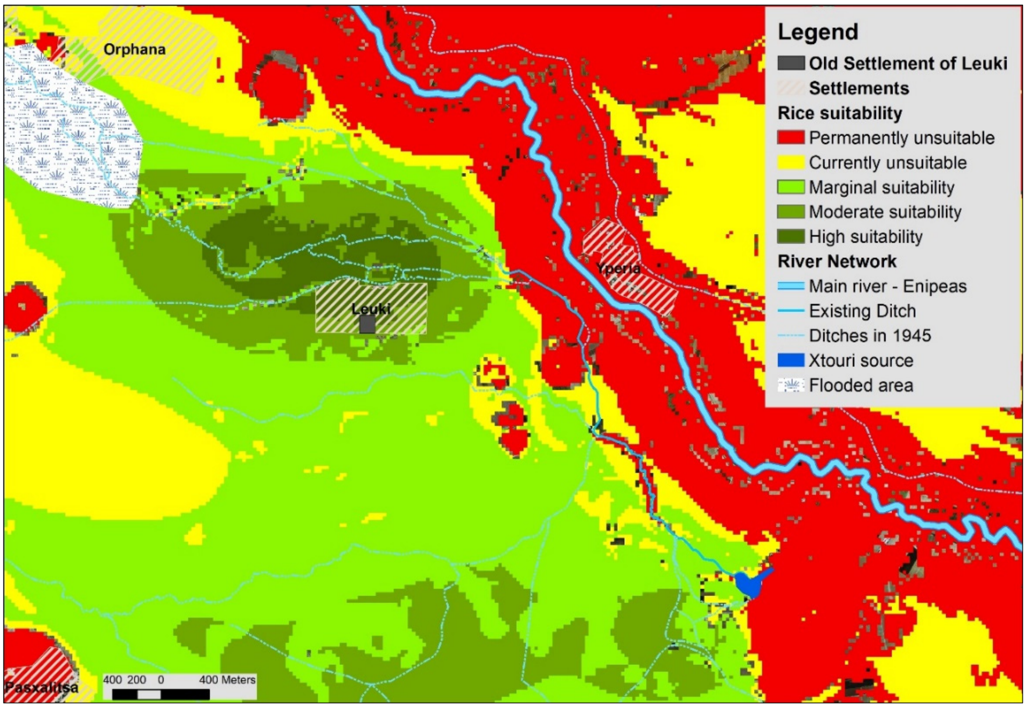


**Figure 8.** Variations in land suitability classes for rice cultivation.

The following is an analysis of the interior of these zones with the application of additional siting criteria for the 15th century rice paddies. One of the main criteria is the surface area required for rice cultivation. The Ottoman registers of 1454 state that rice cultivation in this community occupied an area of approximately 3.5 hectares, for which, however, a total of 7 hectares was reserved if the additional area necessary for crop rotation is considered. At the same time, additional siting criteria have been used as noted below.

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*4.2. Identifying the Location of Paddy Fields*

For the most accurate siting and layout of the paddy field, a second set of determining factors is taken into account:

- Zone dedicated to crops for own personal consumption (legumes, etc.) due to specific soil characteristics. It is located at a distance of 600 m, east-southeast of the village of Lefki, in the zone of sandy soils, fragmented into small parcels of 0.5-1 ha. This zone lies outside the flood zone upstream of the channel branches, and therefore could not be used for rice cultivation.
- Information from residents that the toponym "the rice" extended northeast of the village of Lefki above the road connecting the villages of Hyperia-Lefki.
- The zone crossed by the 1st and 2nd forks in the channels from the central ditch. The choice of channels enables better water management and uninterrupted flow for the neighbouring communities, as required by the regulation.
- Adequate distance from the big landowner’s residence (konak) (to avoid humidity and mosquitoes). For this purpose, a 200 m exclusion zone was created.
- Leake’s report that rice paddies surrounded the village for a mile. It is argued that Leake's ability to identify rice paddies from a distance of approximately 1600 m in December, i.e. when the rice harvest and water draining had already been completed, was based on the existence of bunds and special constructions, known as “tigania”.
- The directions of the strongest winds in the area in relation to the position and layout of the paddy field. The west and north-west layout of the artificial channels north of the village, combined with the strong local westerly and north-easterly winds, indicate the existence of two potential adjacent locations for a rice paddy (A and B) as shown in the following figure (Figure 9). At these locations, the layout of the paddy basin was determined based on the layout of the channels.

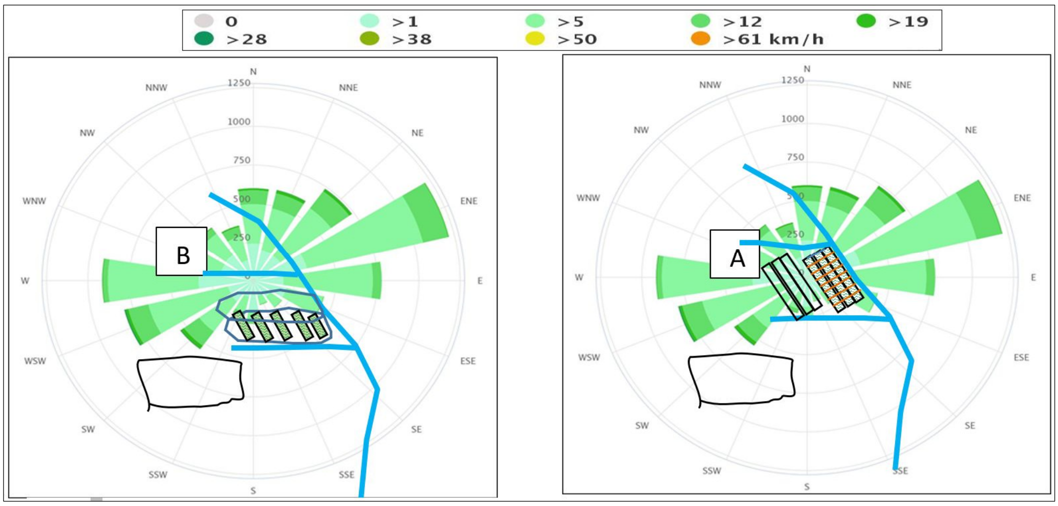


**Figure 9.** Position and layout of the paddy field in relation to wind directions.

In view of the above criteria and the necessary conditions for rice cultivation, two candidate areas (within the initial suitability zones) which do not exceed 11.5 ha were identified (Figure 10). In these areas, land levelling, the most important task for paddy fields, is easy since along the approximately 800 m separating the eastern and western edges, the difference in elevation does not exceed 1 m. This means that a difference between the highest and lowest point of the paddy basin of between 2-5cm/100m is easily achievable.

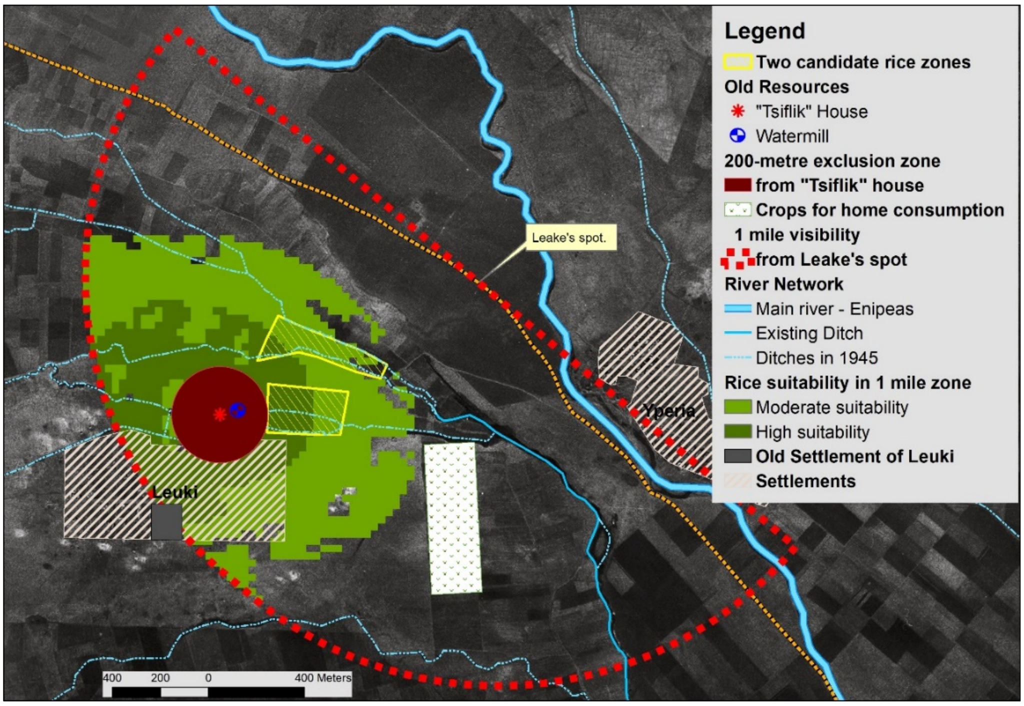


**Figure 10.** The two candidate zones for rice cultivation.

There are two scenarios for the location and layout of the rice paddies based on: (a) the agronomic requirements of the crop (rotation of plots, soil characteristics), (b) the topography and the network of channels (slope, river flow) in combination with the wind directions and (c) the estimation that the total area dedicated to rice cultivation (cultivation and crop rotation) did not exceed 7 ha. As the study shows, these two possible rice paddy locations are almost adjacent and have the same characteristics that are required for the effective operation and yield of a rice paddy. In both cases, the results highlight the optimal one:

- siting of the paddy fields chosen in order to combine: (i) soil characteristics, (ii) use of the local hydrographic network (other crops, sharing water with downstream communities through which the ditch passes, and (iii) the appropriate location and layout of the paddy field to prevent impacts on health (malaria) and the crop due to winds.
- integration of the paddy field into the mixed production system and the local agro-ecological system (biodiversity, ecological water, etc.) without impacting them. Although the spatial-agronomic criteria would allow the expansion of the paddy field, its surface area seems to be further dependent on the obligation of the community of Lefki to supply the other communities with part of the water from the ditch.

## 5. Discussion

Historical retrospection for the reconstruction of the paddy field in the community of Lefki faced two challenges. On the one hand, the lack of experience of the local community due to the abandonment of rice cultivation before 1880 and the degradation of the local eco-system as a result of the implementation of an intensive agricultural model since 1960. On the other hand, approaching rice cultivation as inherited knowledge, through the current needs of territorial dynamics and agro-ecological transition. The applied participatory-interactive methodology functioned as a process to safeguard past knowledge and practices related to spatial organisation and the sustainable management of resources from oblivion. In view of these challenges, the research results are viewed from two perspectives.

The first concerns the participatory, interactive methodology itself. This combines: (a) the direct insight provided by the 3D geovisualisation of the data from the description (in situ), (b) the alternation between visualisations that use geospatial information (aerial photographs, satellite

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images, etc.) with different spatial and temporal resolutions (in visu), and (c) the collective memory of local actors surrounding the history of places [55]. Its application is organised by a process of successive phases identifying the early 19th century space using a combination of sources, methods and representations. Technically, the creation of 3D-GIS interactive representations combined low-resolution black and white aerial photographs from 1945 with higher-resolution colour images from 2017. By focusing on the co-ordination of available sources, this combination harnesses the spatial dimension of information as an element of spatial subsystems. This process is supported by the 3D-GIS three-dimensional interactive model, contributing to the gradual interpretation and integration in space of heterogeneous information and local collective memory as a source of information. This environment was enriched with additional information such as toponyms, the location of settlements, the road-hydrographic networks, etc. The ability to depict these elements enables the gradual development of this virtual space on the basis of a two-way contribution: the more local actors gradually identify this space, the more it is enriched with additional information.

This methodological process addresses the gap observed in the literature about applications that mainly involve intangible heritage elements in rural areas. Indeed, most applications focus on urban space using 3D representations, and are limited to the present and to issues relating to participatory planning and decision making [56–60]. The methodology addresses this gap by aggregating resources and creating information nodes with potential interconnections. Through navigation in a virtual environment, it integrates and organises this information based on its reference to the position and function of elements of the spatial system (land use and appropriation, networks, etc.). Links, interdependencies and connections between these elements within the spatial systems arise. Combining these systemic interdependencies with the information available reduces the incompatibilities and also creates information synergies. By helping to "awaken" and activate local collective memory, this reconstruction-depiction has led to a continuous improvement in the representativeness of the space and its systems. At the same time, it facilitated the transition of actors and information from past to present and from virtual to real space.

The second concerns the identification of paddy-related elements that allowed the reconstruction and understanding of the organisation of the farming system within spatio-temporal planning. It is noted that identifying the location of the paddy field in the community space was made possible by combining: (a) on the one hand, the reconstruction of the landscape, which acted as a spatial foundation for the identification of land cover and use, the position and function of elements of the spatial system in the area, but also as a reference space for local collective memory and (b) on the other hand, the strong interdependence between the rice cultivation system and the physiography and geomorphology of the area and the various technical and topographical combinations (distance from the source, slopes, water flow/flow control, wind direction, etc.). The visualisation of these combinations through mapping helped, on the one hand, highlight the location and function of these elements within the spatio-temporal organisation of the rice field and, on the other hand, identify the close relationship between rice cultivation and natural resources, revealing relevant knowledge. It therefore clarifies the organisation, in the specific space, of the overall scheduling which regulates, by combining and coordinating, the farming needs of rice in relation to the physiography. This reconstitution of the horizontal organisation of rice cultivation sheds light on its functioning within a coherent vertical organisation regulated by a highly precise regulation, coordinated by the central administration with an interestingly staggered management. Within the community, the multidimensional knowledge of the society of the time is highlighted in terms of establishing the optimal relationship between the zoning and organisation of the rice fields. The methodology succeeds in identifying and projecting in space the locations of the elements and the functioning of the systems (cultivation system, irrigation, etc.), contributing to the understanding of the integration of the paddy field as a subsystem in the wider productive and agro-ecological (biodiversity, ecological water, etc.) system. The detail of the organisation of this integration allows the emergence of values and principles such as the protection of health, respect for the equitable distribution of water to the other communities as a public good, agro-ecological harmony with the conscious preservation of flora and fauna as elements for the reproduction of life, etc. The technical insight of more

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specialized researchers can enrich these insights and further explore to what extent they can support the agro-ecological transition process of areas such as the Lefki community.

### *5.1. The Role of the Represented Space*

It is found that the virtual reconstruction of a paddy field that no longer exists by navigating a not-so-recent past is based, in practice, on the interoperability of an informational, communicative and even anthropological process enabled by the methodology applied. This interoperability is defined as the possibility of interaction between information and communication during a bidirectional journey in space and time during the process of a 3D geovisualisation using appropriate techniques and methods [3,61]. The methodological process followed guides the interaction between information and communication, facilitating the active participation of the community in this retrospection. In this 3D interactive environment, the combination of sources and collective memory produces and corrects information. In other words, a two-way relationship between information and communication is created, driven by collective memory. This relationship is activated by participatory processes which are enhanced by new forms of mapping incorporated in the methodological chain, such as 3D interactive visualisations. The resulting interactivity also fosters a two-way contribution to further improve the representability of the landscape. This virtual environment forms a hybrid space based on the real (that which has been preserved) and the virtual (that which can be represented) space. This space becomes functional through the activation of 3D interactive visualisation models, enabling the connection of different time periods (transition from the pre- to the post- land consolidation period, drainage of the neighbouring lake). In essence, the historical space to which the collective memory refers, is provided to the collective memory as a source of the historical information that the memory itself carries. The incorporation of new technologies into the methodology ultimately enhances community memory as it is able to record both the formal and the more difficult to identify, informal, knowledge and to project it through 3D interactive representations [62].

### *5.2. The Contribution of Past Knowledge to Planning the Future*

By fostering interaction between information from different sources, with the space as a common reference, this interactive methodology extends beyond the simple transfer of information, creating conditions for communication and enabling a joint approach[6] [15–17,20] to knowledge. Through the shift between information, space and the system, actors recognise and register abstract elements of cognitive heritage related to natural resource management as an element of community intelligence. Common inherited knowledge regarding the sustainable management of the relationship between people, animals and natural resources is now transformed into knowledge of territorial local intelligence. For example, knowledge about the functioning of a complex farming system such as paddy fields regains a role in the current management needs of public goods (water, pasture, etc.), contributing to the creation of a Commons institution [63]. By intervening in the creation and/or management of common goods, the community can draw on collective knowledge, values, etc., from the past, which contribute to the organisation of sustainable agro-ecosystems anchored in the space. This contribution is important for rural communities that are being rebuilt and undergoing socio-economic and agro-ecological transitions [64]. The methodological process enriches spatial thinking by facilitating immersion in the past, thus contributing to the "production reorientation" effort of territorial areas and mediating with the outside world [9,64] in terms of their distinctiveness. This readjustment is based on the combination of heterogeneous knowledge and knowledge which creates new knowledge. This knowledge can, in turn, participate in new configurations [66] such as the harmonisation of environmental management and the socio-economic adjustments of the territorial and production space. The methodological process of cognitively organising this knowledge enriches these configurations with the participation of local actors.

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[6] GIS spatial analysis – 3D visualisation (current – past): the contribution of 3D in information extraction

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In particular, it seems that the proposed methodological process of activating a network of sources with a significant flow of information and knowledge, could also contribute to the planning of small-scale territorial development. Although this network is temporary (for the duration of the research), it constitutes a reliable source of inherited knowledge. However, any community seeking to integrate this inherited knowledge into a territorial development and/or agro-ecological transition plan, particularly because of its abstract nature, needs to enter a learning process [67,68]. The combined methodology can, as an informational and interactive system, support such a process. Despite their technocratic nature, when digital tools are combined with the participation of local actors, they offer new possibilities in approaching knowledge and the space as a social creation. They facilitate the functioning of local democracy by supporting consultation, decision-making but also cooperation and coordination, ensuring transparency and trust between actors [55]. They can also help, on the one hand, to strengthen learning capacity and knowledge management at the community level, as a component of the development of a territorial area [69], and on the other hand, to educate the new generation of citizens who envisage the sustainable development and resilience of the place by drawing on knowledge from the past. Lastly, it seems that the technical capacities of the methodology, combined with the qualitative methods of social research, also facilitate the use of this knowledge in territorial engineering [64].

The combined Methodology helps this knowledge participate in the co-construction of territorial knowledge as well as in the processes of territorialisation and sustainable development. Since this knowledge provides elements of specificity and helps harmonise the human-nature relationship, the community would benefit from integrating it into its territorial planning. The resulting knowledge feeds the toolbox of a territorial area that attempts to valorise resources constructed endogenously, contributes to distinctiveness and the agro-ecological transition and, its values are compatible with the objectives of sustainable territorial development [70]. Finally, knowledge from the past and the methodology itself support the integration of agro-ecological and socio-economic adjustments at the level of the territorial area.

## 6. Conclusion

The transition of the global community towards ecology, by complementing the concept of 'local', emphasises the need to re-observe the relationship between natural resources and anthropogenic activities, revalorising past knowledge as well. The interest in reconstructing a highly spatially-anchored rice cultivation system organised five centuries ago is neither limited to a given historical moment nor to the search for an interpretation of the present in that moment [71]. Its value stems from two findings: (a) it transfers experience with timeless values from the past since as it arises from the successful attempt of a centralised administration, such as the Ottoman one, to regulate with the community, the complex relationship between the crop, natural resources and the market, preserving the place of rice, a product which is nutritious and was culturally valuable to the nutritional needs of the time, (b) it illuminates the road to agro-ecological transition and can contribute to new future uses determined by current local (resource specificity,) and global challenges such as sustainable development and climate change. Faced with these stakes, local communities are realising that modernisation alone is not a source of solutions and that heritage is a relevant source. They also realise that this knowledge can contribute to the resilience of local communities, in the form of knowledge capital integrated in territorial intelligence. If the concept of territorial intelligence is therefore linked to the capacity of local actors to collectively obtain knowledge capital, then an interactive methodology can contribute to this integration [72,73]. In this case, past knowledge, with its goal of territorial development and the territorial community as its object [74], acquires a new social utility.

Indeed, the value of this knowledge stems from its reference to the rationale of nature and its contribution to understanding its components before the impact from the adoption of an intensive agricultural model. Projected onto the space, knowledge from the past helps us to see again, albeit virtually, natural features in geographical space and to approach the formulation of the harmony between the countryside and the environment through the human-nature interaction. Finally, it allows us to understand "the contrast between the self-regulation of ecosystems and anthropogenic actions. Following the evolution of the interaction between naturality and spatiality, the contribution of this knowledge, since it arises simultaneously from both spatial and ecological analysis, helps to reposition interdisciplinary approaches to prevent them from being limited to ecology or overlooking the environment and forms or even disregarding the laws of spatial organisation [37].

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